Aerosolization mechanisms of saliva by speech application to pathogens transmission

Our understanding of the vectors of transmission of SARS-CoV-2, the virus causing COVID-19, are advancing rapidly. The important role of aerosols is becoming clear, and because phonation produces aerosols, speech has proven to be a pernicious, invisible, yet potent viral transmission mechanism between asymptomatic individuals in the actual pandemic. But to control transmission and to develop mitigation strategies, it is crucial to understand the typical size distribution of these biological "sprays" of saliva during phonation since it controls their fate. Size, evaporation and aerial transport are indeed intrinsically linked. Medium aerosols of a few to tens of microns can, in principle, remain liquid long enough in a given hygrometry to maintain viral integrity, and therefore infectivity, and yet are small enough to be transported by oral and local air flows.

The mechanisms of saliva aerosolization are yet to be fully understood in the context of phonation. Recently, we showed how phonation of common stop-consonants, form and extend salivary filaments after a film destabilization, in a few milliseconds, as moist lips open or when the tongue separates from the teeth (Figure 1A) [1]. We have shown how saliva viscoelasticity is essential for stabilizing thin filaments, while fast airflow associated with the plosion of voicing stop-consonants such as /p/ or /b/, induces centimeter-scale stretching of these filaments and their subsequent thinning to tens of microns in diameter, and finally breaking into speech aerosols (see figure 1B). These observations revealed a generic hydrodynamic instability for saliva, and inspired a new mitigation strategy to reduce these emissions during speech by changing saliva rheology. We demonstrated that the use of a simple lip balm led to a dramatic decrease of emission by elimination of filament stretching (figure 3C). However, one of the major challenges is to observe this mechanism of aerosolization at the mouth with all its complexity, and understand the role of the different parameters of the problem (viscoelasticity of saliva, airflow, humidity, saliva composition etc…). This original sheet-to-filament-to-droplets transition induced by a complex combination of imposed extension and air flow is not yet understood.

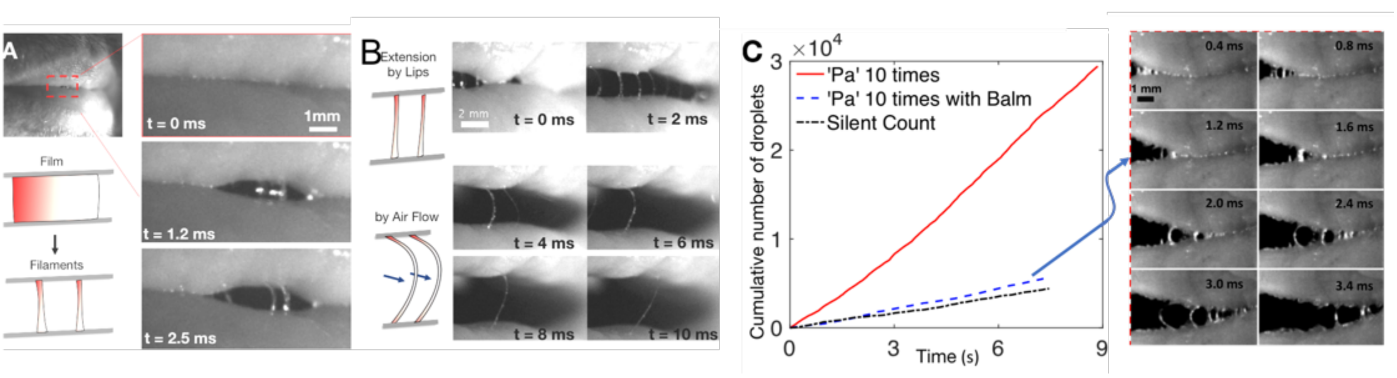

Figure 1 -Film-to-filament-to-droplet. Sequence of images while saying 'Pa' in 'PaPa' with (A) the initial film formation and destabilization to form filaments, (B) subsequent sequence of the aerodynamic extension and snapping of the filaments (C) Sequence of images showing the opening of the lips covered with a lip balm while saying the first 'Pa' in 'PaPa'. (B) Saliva droplet spread between two fingers (left) without and (right) with the balm. (C) Temporal average cumulative number of the light flashes representative of the passage of droplets while saying 10 times 'Pa' over 4 runs with and without the balm [1].

During this thesis, **the PhD candidate will deepen our understanding of the two different steps of the generic instability namely the sheet-to-filament and the filament-to-droplet transition. She or he will combine model experiments, in-line holography approaches coupled to high-speed imaging on both real saliva samples and model complex fluids to decipher the physics underlying these processes. Depending how fast the project advances the student will be involved in studying the history of drying of these generated droplets in order to characterize the physico-chemical history pathogens are submitted to during their airborne transport and what parameters define a "successful" transmission.**

Environment of the project

The PhD student will be part of a consortium of multidisciplinary researchers working together in the field of physics of pathogen transmission (SATIS project) . The candidate will be interacting with physicists, virologists and biologists.

International connection

The candidate will be also collaborating the group of Prof. Howard Stone at Princeton University, who is an expert in hydrodynamics.

Expected Skills

We are looking for a motivated student. The candidate will have a taste for experiments, especially in fluid dynamics. A background in soft matter will be appreciated as well as in image analysis and programming.

References

[1] Stretching and break-up of saliva filaments during speech: a route for pathogen aerosolization and its potential mitigation. M. Abkarian, H. A. Stone, Physical Review Fluids (2020) DOI: https://doi.org/10.1103/PhysRevFluids.5.102301
[2] Biaxial extensional viscous dissipation in sheets expansion formed by impact of drops of Newtonian and non-Newtonian fluids, Louhichi A., Charles C.-A., Phou T., Vlassopoulos Dimitris, Ramos L., Ligoure C., Physical Review Fluids, vol. 5 p.053602 (2020)

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